thousand pounds to the navy vote for three successive years, in order to carry through an undertaking worthy of the maritime position and the scientific reputation of this great empire.

An animated discussion, in which the Duke of Argyll, Lord Charles Beresford, Sir Joseph Hooker, Sir George Nares, Sir Vesey Hamilton, Capt. Wharton, Sir W. Turner, Sir W. Flower, Dr. Buchan, and Mr. W. S. Bruce took part, followed the reading of the paper. All the speakers strongly expressed their conviction that the time had come to make a vigorous attempt to resume the long-interrupted line of advance into the south polar regions by means of a Government expedition.

PHENOMENA OF THE TIME-INFINITESIMAL.[1]

SCIENCE consists in the extension of our knowledge of the external universe, and it brings about this extension in great part by reinforcement of our senses. To bring into the field of observation the very distant and the very small, are therefore regarded as important scientific achievements, and the telescope and the microscope, by means of which this widening of the realm of knowledge has been made, as important implements of research.

Man's relation to time is such that it is difficult to conceive of an instrument which should bring distant events to hand in like manner for inspection. Our time vision turns chiefly in one direction—towards the past—and is obscured by the intervention of something very like a medium or atmosphere, through which we see dimly. As to the future, our thoughts are necessarily confined to matters found by experience of the past to be periodic, or to changes already begun and known by the observation of analogous processes to be likely to run some definite course. In the interpretation of the future by the past, there is much of interest to the physicist; but it is not of this that I would speak to-day. Let us turn our attention rather to the study of minute time intervals in physics—to a consideration of the methods by which we may record what takes place during infinitesimal elements of time. The interest of the physicist in time is confined really to a study of phenomena. He ascribes no property to time itself, beyond defining it after Riemann, as a complexity of the first order.[2]

As between the study of the infinitely great and the infinitesimally small, whether of space or of time, there is a peculiar value to be attached to the latter, because the only methods which have proved the least fruitful in the analysis of the more complex changes which are going on around us, are those which begin with the infinitesimal. We consider an element of mass or of volume, or sometimes merely the element of a surface or line, proceeding then to extend our statements so far as our powers of mathematical expression will permit.

Now the element of time is, of course, purely relative. In certain phenomena the time infinitesimal is so short as compared with any time interval with which we are able to cope experimentally as to be out of reach, just as in special relations the dimensions of the molecule and atom are such that we dare not hope to render these ultimate particles of matter visible even under the microscope. There are periodic phenomena, on the other hand, the periods of which are so great that a lifetime, indeed the entire era covered by history and tradition, affords us a glimpse of but a single time element. Lying between these two there is a great range of phenomena for which the element of time is within our reach. It is by the study of what takes place in such time elements, and the extension of the results thus obtained by analytical processes, that much of our knowledge of physics has been gained. It is to the extension of our powers in the observation of the phenomena of the time interval that we must look in great part for further progress. It has seemed worth while, therefore, to bring together for purposes of comparison some of the methods which have proved fruitful in this respect, and to consider along what line they may be further developed. It is an investigation which will lead us into all departments of science; for phenomena into which the element of time does not enter are unknown.

Since all study of phenomena involves the time element, the consideration of all dynamical problems must begin with the *phenomena* of the *time-infinitesimal*. There are two cases of chief importance:—(1) The study of the time elements of periodic phenomena; (2) the study of beginnings of changes which result from a sudden variation in the condition of equilibrium.

The methods which have been found most useful in the investigation of the phenomena under consideration may be classified as follows:—(1) Visual methods: (*a*) vision by instantaneous exposure, (*b*) vision by periodically interrupted exposure, (*c*) vision by the aid of the revolving mirror. (2) Photographic methods: (*a*) instantaneous exposure of a stationary film, (*b*) photography by the aid of the revolving mirror, (*c*) continuous exposure of a moving plate, (*d*) successive short time exposures of a moving plate. (3) Indirect graphical and electrical methods.

Much of the most important work which has been done in the domain of sound falls within the scope of our present inquiry, and it is in that field that many of the methods just indicated have been developed. The revolving mirror, for example, is a favourite tool of the acoustician; its usefulness is too well known to need mention here, but I wish to remind you that this instrument, chiefly used for the separation of images representing phenomena covering intervals of thousandths of seconds, has been found capable of rendering much briefer events subject to inspection and analysis.

The inventor of the revolving mirror (Wheatstone) found it possible to study time intervals down to within a millionth of a second ("Philosophical Transactions," 1834). He obtained a rate of revolution never since greatly exceeded, I think, of eight hundred revolutions a second. It is evident that he stood at the very threshold of the discovery of the oscillatory discharge, and that it was merely an accident of the relation of resistance and capacity in the circuits which he employed, which prevented him from observing that important form of the electric spark. That he was fully aware of the wide range of investigations to which the revolving mirror is adapted is also clear. He says in the memoir which Faraday presented for him before the Royal Society in 1834: "But this instrument is not confined to observing merely the intermittedness of electric light; whenever a rapid succession of alterations occurs in an object which does not change its place, they may be separately examined by this means. Vibrating bodies afford many instances for investigation; one among these is perhaps worthy to be mentioned. A flame of hydrogen gas burning in the open air presents a continuous circle in the mirror, but while producing a sound within a glass tube regular intermissions of intensity are observed, which present a chain-like appearance, and indicate alternate contractions and dilations of the flame corresponding with the sonorous vibrations of the column of air" (*l.c.* p. 586).

In a later paragraph of the same paper he noted the applicability of the spark in the study of the phenomena of the time-infinitesimal, suggesting a method the importance of which is even now but imperfectly appreciated. "The instantaneousness of the light of electricity of high tension affords the means of observing rapidly-changing phenomena during a single instant of their continued action."

In the hands of Foucault ("Recueil des travaux scientifiques," Paris, 1878), Michelson ("Proc. A.A.A.S.," 1879) also "Papers of Amer. Ephemeris," vols. i. and ii. 1882), and of Newcomb ("Astro. Papers of Amer. Ephemeris," vol. ii.) the revolving mirror has given us our best determinations of the velocity of light; in those of Feddersen ("Beiträge zur Kenntniss des electrischen Funkens, 1857.") Also *Pogg. Ann.* 103, 113, 116 (1859 to 1862), Rood (*Amer. Journal of Science*, vol. ii. 111, p. 160), Trowbridge (*Amer. Journal of Science*, vol. xlii. 111, p. 223), and Boys (*Philosophical Magazine*, vol. xxx. 111, p. 248) and others it has made it possible to resolve the oscillatory spark into its elements.

Feddersen's experiments are especially noteworthy because he succeeded (in 1862) (*Pogg. Ann.* 116, p. 132) in photographing the discharge of the Leyden jar, securing an excellent record of the images seen in the revolving mirror. We are apt at the present day to look back to the introduction of the dry plate as the step necessary to the application of photography to the study of fleeting phenomena, but certainly the results obtained by this early investigator, who used the ordinary wet-plate process of his time, are not inferior in definition or in detail to any which have been published in recent years. Feddersen's researches are indeed worthy of all admiration. He used a concave mirror, giving excellent images when driven at a speed of one hundred revolutions a second. The velocity was under the regulation to within two per cent., and the millionth of a second represented not merely an appreciable distance upon the negative, it was an *easily measurable* quantity.

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[1] An address delivered by Prof. E. L. Nichols before Section B (Physics) of the American Association for the Advancement of Science. Madison meeting, August, 1893.

[2] "Eine einfach ausgedehnte Mannigfaltigkeit." (Riemann: Ueber die Hypothesen welche der Geometrie zu grunde liegen. Werke p. 257.)

More than thirty years ago this German physicist stood, as Wheatstone had done nearly half a century before him, in the very gateway of the domain in which such activity has shown itself of late—the domain of electrical resonance. He was not only the discoverer along experimental lines, of the oscillatory discharge and the demonstrator of the existence of effects which had already been embodied in the analytical work of Helmholtz, Thomson, and Kirchhoff; he anticipated also many of the discoveries of later investigators, and worked out quantitatively the dependence of the rate of oscillation upon capacity, induction, and resistance. Two of Feddersen's photographs have been brought to general notice by reproduction in the fourth volume of Wiedemann's "Electricität." There is another set which I consider even more significant, showing the increase in the number of oscillations with diminishing resistance. It is copied in *fac simile* from the original plate in Fig. 1.

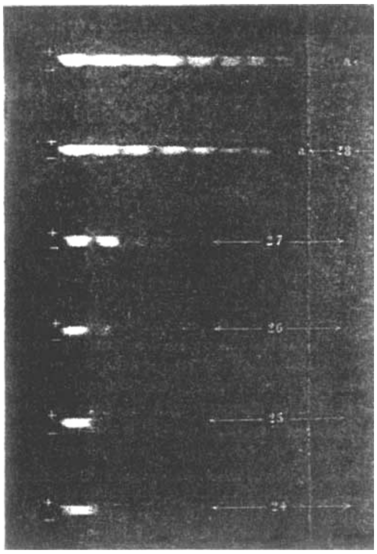

FIG. 1.

Another forerunner in the development of the methods which it is my privilege to consider, was Prof. E. W. Blake, of Brown University. His results, too, have become classical; but I refer to them because they are related in ways not always recognised in later work. We are all familiar with his interesting photographs obtained by speaking into the mouthpiece of a Bell telephone (Blake, *Am. Journal of Science*, vol. xvi. (3) p. 57), to the diaphragm of which was attached a rocking mirror. Records obtained in a variety of other well-known ways, of some of which I shall have occasion to speak, indicate that these photographs do not give a complete trace of the vibrations which go to make up the articulate utterances by means of which they were excited, but the method is of interest in three particulars :—

(1) It is one of the earliest attempts to substitute photography for vision in the study of the transient phenomena of the sound wave.

(2) It substitutes a moving sensitive plate for the revolving mirror.[1]

(3) It is a distinct forerunner of the method applied some years later with somewhat better success by Froehlich to the analysis of alternate current phenomena.

Throughout the history of the study of the phenomena of the time-infinitesimal we find the tendency to be to supplant visual methods by methods of photographic record. One of the most noteworthy achievements in experimental acoustics, for example, is the application of the manometric flame to the study of sound waves. The drawings made by Kœnig (*Annalen der Physik*, vol. cxxii. p. 666; also in his "Experiences d'Acoustique," pp. 47–84) in illustration and verification of the phenomena of the organ-pipe and of the analysis of complex sounds, have been admired by all of us; and the repetition of his experiments has delighted an entire generation of demonstrators in physics. In how many minds the question of the feasibility of photographing the manometric flame has arisen I do not know, but quite recently it has been shown by Doumer (*Comptes Rendus*, 103 and 105), and independently by Ernest Merritt (Proc. A.A.A.S. 41, p. 82; also *Physical Review*, vol. i.) in a paper read before this section, that by surrounding the sensitive flame with a mantle of free oxygen (after the method of what was once known as the "Budde" light), sufficient actinic intensity may be obtained to ensure an excellent photographic record on a rapidly moving plate. The results of such photographs applied to the analysis of vowel sounds give evidence of the extraordinary fidelity of the sketches published by Kœnig. They also afford a basis for the study of timbre of the sounds to which they correspond, which is open to one objection only, viz. to the uncertainty as to the influence of the inertia of the diaphragm upon the character of the image. Of this source of error I shall have more to say in connection with some other researches.

Other interesting examples of the study of the time-element might be drawn from this field; indeed, the science of sound is of necessity largely made up of such work. The beautiful photographs of vibrating strings by Menzel and Raps (*Annalen der Physik, N.F.* 44, 1891, p. 623), which are so fitting an appendix to the earlier labours of Helmholtz (*Die Tonempfindungen*, p. 137), may serve to illustrate the usefulness of the method of photography on a moving plate.

In the study of periodic phenomena two distinct methods of investigation have been established. The first of these consists in the isolation of a desired element of the cycle at each repetition for as long a time as may be necessary to obtain a satisfactory record of the existing conditions. By the selection successively of many neighbouring elements, we get in this way at last the data from which to construct a complete diagram of the cycle.

This principle has been most fruitful in enabling us to analyse periodic processes not easily approachable by more direct means. The most notable application has been that which is commonly spoken of as the "method of instantaneous contact," well known to the student of alternating current phenomena.

It is to Joubert[1] (1880) that we owe this ingenious adaptation of the device of properly timed repetitions of instantaneous observations of periodic phenomena (a principle which underlies the phenakistoscope and similar well-known instruments). He made use of it in the study of the changes of potential in the circuit of the alternating current dynamo, and between the terminals of the Jablochkoff candle.

In the same year the method was discovered independently, and applied to the study of the Brush arc-lighting dynamo by B. F. Thomas.[2] Joubert pointed out the method of using the quadrant electrometer in alternating circuits, also that the galvanometer might be utilised. ("On peut mesurer cette intensité par l'electromètre mais on peut aussi employer le galvanomètre puisque les contacts successive correspondent toujours a une même phase du courant.") He discovered the retardation of phase in the current curves of the alternating dynamo, and the peculiar distortion of the curves in the circuit containing an arc lamp, a matter more fully investigated at a later day by Tobey and Walbridge.[3] Thomas during this first period in the history of the Joubert method used a ballistic galvanometer and condenser.

The periodic phenomena of the alternating current circuit have been among the most important to which the study of the time-element has been applied, and it is to the method of instantaneous contacts that we owe much of the progress of the last thirteen years. It is interesting to note the extension of this method in the study of a variety of allied phenomena. After the publication of Joubert's papers the method seems to have come into common use in the physical laboratories, particularly in the exploration of the fields of continuous current dynamos and motors.

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[1] Stein, in a paper cited by Prof. Blake, *Pogg. Ann.* 159 (1876), describes a similar device, but it is difficult to ascertain from his paper to what extent he succeeded with his experiments.

[1] "Sur les Courants alternatifs et la force electromotive de l'arc electrique." *Comptes Rendus*, vol. xci. p. 161, July 19, 1880.

[2] "Observations on the electromotive forces of the Brush dynamo-electric machine." (title only.) Proceedings A.A.A.S. vol. xxix. p. 277 (1880). Prof. Thomas gave the results obtained, and described the method eleven years later in a communication to the Institute of Electrical Engineers, entitled "Notes on Wiping Contact Methods for Current and Potential Measurements," Translations of the American Institute of Electrical Engineers, vol. ix. p. 263.

[3] "Investigations of the Stanley Alternate Current Arc Dynamo." Trans. Am. Inst. Electrical Engineers, vol. vii. p. 367.

In 1888 it was applied by Duncan, Hutchinson, and Wilkes ("Experiments on Induction Coils," *Electrical World*, vol. ii. p. 160, 1888) to the study of induction coils and transformers. To them we owe the first set of complete diagrams relating to the performance of this class of alternating current apparatus. In the same year Meylan ("Sur les Appels Magnetiques," *La Lumière Electrique*, xxvii. p. 220, 1888) used an interesting modification of the method in the investigation of the vibratory magnetic call-bell of Abdank.

In the same year appeared the first definite data with reference to the Westinghouse alternating dynamo, at the hands of Messrs. Searing and Hoffmann ("Variation of the Electromotive Force in the Armature of a Westinghouse Dynamo," *Journal of the Franklin Institute*, vol. cxxiii. p. 93), of Stevens Institute. Then followed in the order named the researches of Ryan and Merritt ("Transformers," Trans. Am. Inst. Electrical Engineers, vol. vii. p. 1, 1889), Humphrey and Powell ("Efficiency of the Transformer," *Ibid*, vol. vii. p. 311), Tobey and Walbridge (*Ibid*, vol. vii. p. 367), of Marks (*Ibid*, vol. vii. p. 324), of Herschel (*Ibid*, vol. vii. p. 328), of Fortenbaugh and Sawyer (*Ibid*, vol. vii. p. 334).

In all these investigations the methods under consideration have been used with varying accessories in the problem of the transformer.

In 1890 it was applied under much more difficult conditions to the analysis of the "ball and point effect" by Archbold and Teeple (see Nichols, "On Alternating Electric Arc between a Ball and Point," *American Journal of Science*, vol. xli. p. 1).

In 1891, Thompson ("Study of an Open Coil Arc Dynamo," Trans. Am. Inst. Electrical Engineers, vol. viii. p. 375) determined the intricate changes of induction in open coil arc lighting machines by means of the same method, and Ryan ("Relation of the Air Gap and the Shape of the Poles to the Performance of Dynamo-electric Machinery," *Ibid*, p. 451) utilised it in his investigations of the influence of the air gap upon the performance of dynamos and motors. In 1892, Duncan ("Note on some Experiments with Alternating Currents," *Ibid*, vol. ix. p. 179) described modifications of the method of instantaneous contacts by means of which the rapidity of reading is greatly enhanced.

During the present meeting, you will doubtless have the pleasure of listening to a description of the applications of the same device to the study of electrostatic hysteresis. (Reference is here made to the paper presented by Messrs. Bedell, Ballantyne, and Williamson: "Alternate Current Condensers and Dielectric Hysteresis," *Physical Review*, vol. i. p. 91. Subsequent note.)

Such has been, in brief, the history of a method by means of which in greater degree than of any other we have been able to extend and complete our knowledge of alternating current phenomena.

To the practical electrician and to the theorist alike, the domain has been one of the most attractive of those which have been developed in recent years. To the electrical engineers of the younger generation the very complexity of alternate current theory has proved a benefit. It has forced them to increased mathematical proficiency and to more rigorous thinking; it has, indeed, served as an excellent source of discipline. What the problems of submarine telegraphy did for the English electricians who served their apprenticeship during the early days of the cable-laying industry, compelling the development of those sturdy qualities which have been so highly serviceable in every branch of electrical progress since, the intricacy of alternate current practice is unquestionably doing for the younger school which is growing up to-day in this country. The difficulties which have to be met and overcome in this field of work will have an excellent influence upon the manner in which the problems of the future will be approached.

Another investigation, which owes its existence to a most ingenious application of this same principle of instantaneous contacts periodically repeated, is well known to all of you. I refer to Prof. E. H. Hall's[1] study of periodic heat-flow in the cylinder walls of the steam-engine by means of thermo-elements embedded within the metal and connected momentarily during a selected time-element in the course of each stroke with a sensitive galvanometer. To my mind no more interesting example of the indirect method of studying the phenomena of the time-element could be found than this suggestive memoir.

The method of instantaneous contacts has been a fruitful one, and productive of high results, but it does not yield a knowledge of any individual time-element, nor the picture of any single completed cycle. Numerous attempts to record single cycles have been made, the results of which are of considerable interest, because they deal with the more direct study of the time-infinitesimal.

The device which lay nearest to hand, and which by its performance seemed to promise success in this direction, was the magneto-telephone. The investigations of Mercadier (*Journal de Physique*, vol. ix. pp. 217 and 282) had already paved the way to some extent, when Froehlich described his experiments upon the optical representation of the movement of the diaphragm of the telephone, followed almost at once by Thomson.

Froehlich[1] reported his preliminary results to the Electrotechnische Verein of Berlin, in 1887. Elihu Thomson ("An Indicator for Alternating Circuits," *La Lumière Electrique*, vol. xxvii. p. 339 (1888) brought out his indicator for alternating circuits, an instrument in which the movement of a diagram was amplified by levers, and then made visible by optical means (or photographed) in the same year. Froehlich's method in its complete form, including the photography of the images from the involving mirror,[2] was first described in the year 1889. Some of the curves published in the papers just cited, and particularly the experiments shown in the exhibition of the method at the Frankfort Electrical Exposition of 1891, are most striking, but considering the method by which they are produced, the question inevitably arises as to the part played by the inertia of the moving masses.

Froehlich himself points out the necessity of great care in the matter of the adjustments, and of distinguishing the natural oscillation of the plate, which are frequently superimposed upon those to be recorded. Some experience with Froehlich's method has convinced me that not only is extraordinary skill necessary in order to obtain, by means of a mirror attached to the diaphragm of a telephone, curves which should represent, even with a fair approximation, the law of whatever periodic changes we may desire to record, but that the attainment of the proper adjustment is a matter so entirely fortuitous, and its maintenance so uncertain, as to deprive the method of much of its usefulness. One may indeed hope to get, by means of successive adjustments, curves which correspond to a known type, but whether in passing to new and unknown types the apparatus retains its faithfulness, is always a question.

By way of illustration, I introduced three of an extended series of curves obtained by this method with a telephone in circuit with an alternating current dynamo. The character of the cycle had been determined by the method of instantaneous contacts. The true cycle was represented by a curve of sines, but with the apparatus under consideration complex curves of the kinds shown in figures 2 and 3 were the rule; curves even approximating to simple sinuosity were the rare exception.

The difficulties of the method lay not merely in the tediousness of adjustment, but rather in the tendency to revert to complex forms under changes of condition so slight as to be entirely beyond control. The remedy clearly consists in the elimination of mechanism and the reduction of inertia of the moving parts. Following the suggestion of an assistant, Mr. E. F. Northrup, I tried the following experiments:—

A mercury stream flowing from the contracted nozzle of a funnel (Fig. 4) was made to pass between two metal terminals which were attached to the poles of a large Holtz machine. A portion of the falling column of mercury within the electrostratic field was illuminated by means of an arc lamp, and so much of it as could be seen through a horizontal slit was photographed by transmitted light. The sensitive plate was given rapid vertical motion through the field of the camera. When the machine was out of action there resulted a vertical trace running the length of the developed plate. As soon as the machine was put into operation, deflection of the mercury stream occurred. It was the object of the experiment to determine the performance of the stream under the sudden fluctuations of the field which occurred when the Holtz machine was under rapid discharge.

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[1] "A Thermo-Electric Method of Studying Cylinder Condensation in Steam-Engine Cylinders." Trans. Am. Inst. Electrical Engineers, vol. viii. p. 236.

[1] "The Optical Representation of the Movements of a Telephone Diaphragm." *La Lumière Electrique*, vol. xxv. p. 180 (1887).

[2] Froehlich: "Ueber eine neue Methode zur Darstellung von Schwingungskurven." *Electrotechnische Zeitschrift*, bd. x. pp. 345, 369 (1889).

Fig. 5 is from a photograph taken when nearly one hundred sparks a second were passing between the poles.

Other photographs were obtained in a similar manner, the deflecting forces, however, being due to the action between the lines of a stationary magnetic field and those of an alternating current traversing the mercury column. The arrangement of the apparatus is shown in Fig. 6. The mercury stream was introduced into the circuit of the alternating current dynamo, already made use of in the experiments upon Froehlich's method. It flowed through a strong magnetic field with horizontal lines. The transverse oscillations of the mercury under these conditions were very apparent. When photographed by means of a camera with optical axis parallel to the lines of force, the stream strongly illuminated from behind and viewed through a narrow horizontal slit, as in the previous experiment, a sinusoidal trace was obtained. All the complexities of the telephonic trace disappeared in these records, and curves corresponding to those of the method of instantaneous contact were always produced. The experiment was made by Mr. Henry Floy, to whose efforts the photographs by Froehlich's method are also due. This method has not been further developed. I introduce it here to show that increased accuracy of record may be looked for as the result of reducing in any practicable manner the mass of the indicating device.

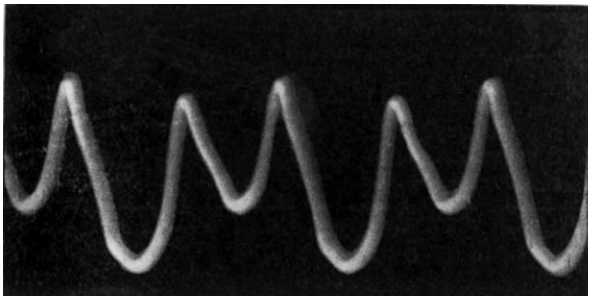

FIG. 2.

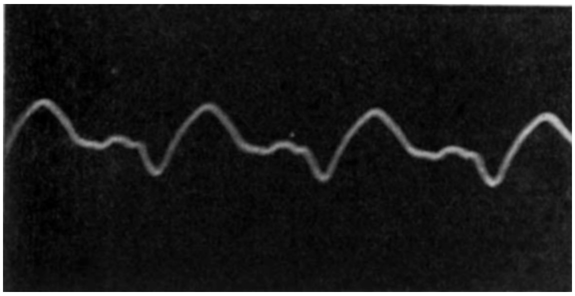

FIG. 3.

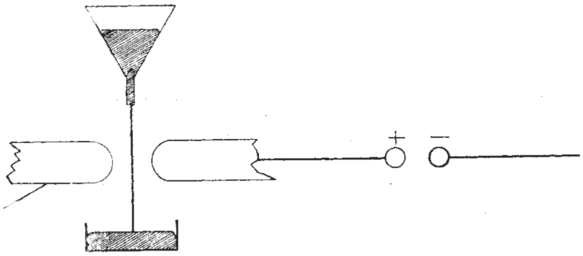

FIG. 4.

Another attempt to record single periods in dynamo-electric work should be mentioned here. It is described by Moler[1] in a recent paper. By means of a D'Arsonval galvanometer with a period of vibration of a few thousandths of a second, curves of varying potential are traced, which show excellent agreement with measurements by the method of instantaneous contacts. The instrument is not free from the errors due to inertia. It is reliable only in recording changes of period considerably greater than its own, but its use is a step in a direction along which progress may he looked for.

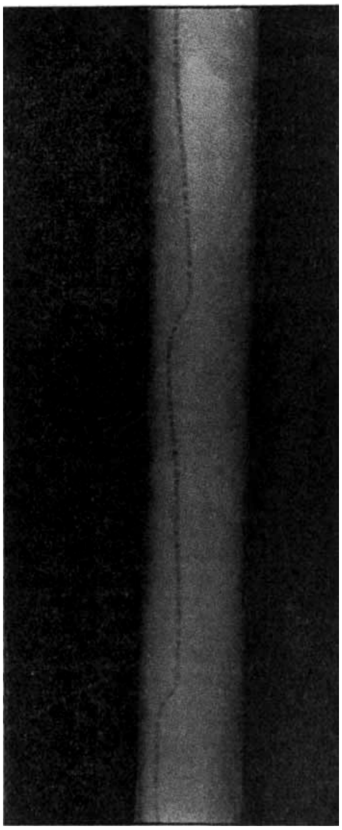

FIG. 5.

Thus far I have dealt with methods of studying periodic changes, the time-elements of which are easily within reach through experimental devices. I might have devoted myself with as good reason to the consideration of recent advances in the study of electrical oscillations of a higher order of frequency. This is a department of physics in which much has been done of

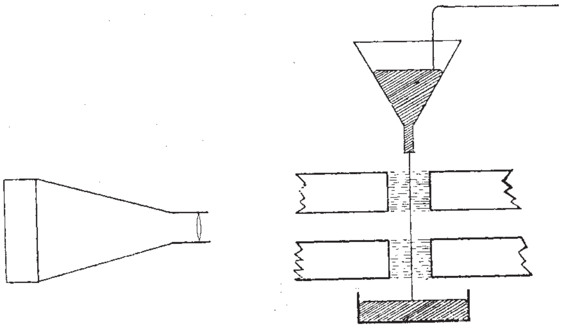

FIG. 6.

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[1] "A Dynamo-Indicator, or Instantaneous Curve-writing Voltmeter." (Trans. Am. Elec. Engineers, vol. ix., p. 223.)

late, but so much has been written at second-hand, as well as in the way of original treatment, that further reiteration is uncalled for. The work of Hertz and of his host of followers is familiar to us all. In the study of electrical oscillations even of very high frequency, photography has been used with success, and details of the phenomena of time-elements truly infinitesimal have been secured. By the labours of Wiener[1] waves of a still higher order than those which have occupied the attention of the electrician have been photographed, and a new field of the greatest promise has been thrown open to the optician. The isolation of a single light vibration may indeed still be as far from us as is the inspection of the molecule by means of the microscope, but in the meantime we have in the photography of a system of standing light-waves, an achievement well worth celebrating.

In the investigation of the phenomena of the time-infinitesimal, so far as periodic changes are concerned, we see that the experimenters of the present time are gaining much of detailed knowledge. There is another field equally important, in my opinion, which is as yet for the most part unexplored. The study of the beginnings of changes brought about by abrupt shifting of the conditions of equilibrium is one from which very much may be expected. Already suggestive beginnings have been made, but the researches have not been pushed to the limit of the experimentally possible. Oftentimes interesting observations of what might be termed "startling phenomena" have been recorded, but quantitative results are lacking. Take for example the brilliant work of Becquerel (*Comptes rendus*, 96, pp. 121, 1215, 1853) with the phosphorescope. What a mass of fascinating and suggestive material that savant has gathered into the first volume of his book on light! (*La Lumière*, i. pp. 206–422.) What a world of interesting material these preliminary observations present to him who shall undertake to determine quantitatively, wave-length by wave-length, the changes which the radiations from the numerous luminescent materials undergo, beginning with the instant of exposure and following the vanishing light until it is gone.

Of a few isolated cases which have been forced upon us by their practical importance we have some complete knowledge already. With the phenomena in cables when current is suddenly introduced or circuit is broken, we are reasonably familiar. The case of the charge and discharge of condensers has been treated analytically under assumptions the precise truth of which is still to be verified. The detailed study by experiments carried to the utmost refinement, of the very cases which seem to have been most completely covered by theory, is especially important; since in this way only can the assumptions upon which our analysis is based be rigorously determined, and the necessity of modifications be ascertained. For some of this work methods already in use in the study of periodic phenomena will suffice. The curve-writing voltmeter, for example, may be made to give records running to within a thousandth of a second of the instant when a process such as electrolysis, electrolytic polarisation, voltaic action, or the charge and discharge of a condenser begins. Instruments such as the von Helmholtz pendulum, for the isolation of definite small time intervals, may also be applied to a great variety of progressive phenomena, enabling us to approach by successive steps almost to the very beginnings of the changes to be analysed. Concerning known methods let me point out, in conclusion, that photography with the moving plate is a means, the limitations of which have not yet been discovered. It is equally applicable to periodic and to progressive phenomena, often with results of unexpected beauty and significance.[2]

The remarkable experiments of Mach (*Wiener Sitzungsberichte*, 95, p. 764, also 97, p. 41) and of Boys ("On Electric Spark Photographs," &c., NATURE, vol. xlvii. p. 415) indicate that the dry plate is still abundantly exposed within intervals so short that the swiftest of modern projectiles give images as of a body at rest.

The laws of electrical resonance have already been so far determined that we can construct condensers, the duration of the discharge of which is a matter of computation, and the precise moment of the discharge of which after a given event is quite within control. This single device, consisting of the exposure of the photographic plate by means of a properly timed spark, brings under observation a set of time intervals of a new and higher order of brevity. Much is destined to be learned by means of it concerning the nature of matter, and much more, I think, from other, possibly still more powerful, methods which will doubtless be developed when the importance of the study of the time-infinitesimal is more generally recognised.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—At a meeting of the Ashmolean Society, held at the Museum on Monday, 27th inst., Prof. Odling was elected President for the ensuing year, and Messrs. F. J. Smith and G. C. Bourne were re-elected Secretaries. Mr. E. J. Stone read a paper on the rainfall at Oxford during the last seventy-eight years, and Prof. E. Ray Lankester read a paper on fresh-water jelly-fishes.

At the meeting of the Junior Scientific Club, on Friday, 24th inst., papers were read by Dr. Ritchie, on anthrax spores and bacilli; by Mr. G. B. Cronshaw, on explosions in coal-mines; and by Mr. A. L. Still, on plants and their standing army.

CAMBRIDGE.—The Special Board for Physics and Chemistry report that the Cavendish Laboratory, founded and equipped by the munificence of the late Duke of Devonshire, has become incapable of accommodating the large number of students desiring tuition in Physics. In the present term no less than 135 students are at work in a disused galvanised iron dissecting-room, which, on its vacation by the Professor of Anatomy, has been placed at the disposal of the Professor of Physics as a temporary laboratory. Its site will, however, soon be required for the Sedgwick Memorial Museum of Geology, and the Board feel that the time has come for the permanent extension of the Cavendish Laboratory. An adjoining site is available between it and the Engineering Laboratory; but the problem of funds for building and equipment is less easy to solve, unless a benefactor as generous as the late Chancellor should make his appearance. The high position deservedly held by the Cavendish Laboratory, entrusted as it is with much work of national importance, makes it reasonable to hope that Prof. J. J. Thomson will be able to obtain the means for the desired extension.

Mr. W. Gardiner and Mr. A. C. Seward have been reappointed University Lecturers in Botany, and Dr. Hill, Master of Downing College, Lecturer in Advanced Human Anatomy, for five years. Dr. Hill has also been appointed Chairman of the Examiners for the Natural Sciences Tripos.

The Local Examinations Syndicate report that the work done in the scientific branches of the Higher Local Examinations during the past year was on the whole satisfactory. Imperfect experimental work in chemistry, and lack of practical instruction in zoology, are among the weaker points revealed.

The Examinations in Sanitary Science seem to be increasingly appreciated by medical men. During the present year eighty-seven candidates have presented themselves, and of these fifty-eight received diplomas in Public Health.

THE *Times* correspondent at Paris says that an International University alliance is in course of formation there. Its object is to facilitate the passing of students from one University to another, to promote travelling scholarships and the exchange of information, to multiply periodical celebrations, and to "draw the attention of the Universities to the question of introducing greater justice into international relations."

SCIENTIFIC SERIALS.

Wiedmann's Annalen der Physik und Chemie, No 11.—On the speed of electrolytic ions, by F. Kohlrausch. This is a compilation of tables of absolute velocities, of mobilities, and of coefficients of electrolytic friction according to the latest and most reliable data.—Contributions to the knowledge of the absorption and branching of electric oscillations in wires, by Ignaz Klemencic.—The resistance which causes evolution of heat during the passage of very rapid oscillations depends upon the magnetic permeability of the wire, but in a different

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[1] "Stehende Lichtwellen und Schwingungsrichtung des polarisirten Lichtes." *Annalen der Physik N.F.* vol. xl. p. 203.

[2] In photographing the alternate current arc a single exposure of a continuous current lamp upon the moving plate, by way of check, brought out the seat and precise nature of the hissing of the arc in a manner scarcely to be reached in any other way. For the method used, see "A Photographic Study of the Electric Arc," Trans. Am. Inst. Electrical Engineers, vol. viii. p. 214, 1891.